



RESEARCH DEPARTMENT

REPORT

---

## **Revised background noise criteria for broadcasting studios**

D.J. Meares, B.Sc.(Eng.), C.Eng., M.I.E.E., M.I.O.A.  
K.F.L. Lansdowne



**REVISED BACKGROUND NOISE CRITERIA FOR BROADCASTING STUDIOS**  
**D.J. Meares, B.Sc.(Eng.), C.Eng., M.I.E.E., M.I.O.A.**  
**K.F.L. Lansdowne**

**Summary**

*To achieve the correct working conditions in its studios, the BBC has, for many years, specified the maximum level of background noise that can be tolerated. This Report examines the 1968 noise criteria bearing in mind the performance of the current broadcasting network, and concludes that revisions are necessary. Based on a study of estimated and measured signal-to-acoustic noise ratios that are typical of programme-signal output, recommendations are made to revise the noise criteria.*

Issued under the authority of



**Research Department, Engineering Division,  
BRITISH BROADCASTING CORPORATION**

August 1980  
(PH-215)

Head of Research Department

**This Report may not be reproduced in any form without the written permission of the British Broadcasting Corporation.**

**It uses SI units in accordance with B.S. document PD 5686.**

# REVISED BACKGROUND NOISE CRITERIA FOR BROADCASTING STUDIOS

Section	Title	Page
	<b>Summary</b> .....	<b>Title Page</b>
<b>1.</b>	<b>Introduction</b> .....	<b>1</b>
<b>2.</b>	<b>Studio sound pressure levels</b> .....	<b>1</b>
<b>3.</b>	<b>Signal-to-acoustic noise ratio calculations for radio studios</b> .....	<b>2</b>
	3.1. Source of noise .....	2
	3.2. Current method of measuring signal-to-noise ratios .....	2
	3.3. Microphone type .....	3
	3.4. Position of microphone .....	3
	3.5. Signal compression .....	3
	3.6. Signal-to-noise ratios .....	4
<b>4.</b>	<b>Noise levels in television studios</b> .....	<b>4</b>
<b>5.</b>	<b>Measurements on radio and television programmes</b> .....	<b>5</b>
<b>6.</b>	<b>Comparative signal-to-noise figures</b> .....	<b>5</b>
<b>7.</b>	<b>Revised criteria</b> .....	<b>8</b>
<b>8.</b>	<b>Practical implementation</b> .....	<b>11</b>
<b>9.</b>	<b>Conclusions</b> .....	<b>12</b>
<b>10.</b>	<b>Acknowledgements</b> .....	<b>12</b>
<b>11.</b>	<b>References</b> .....	<b>13</b>
	<b>Appendix I: Microphone Directivity</b> .....	<b>14</b>
	<b>Appendix II: Revised Criterion – Tabulated Values</b> .....	<b>15</b>

© BBC 2006. All rights reserved. Except as provided below, no part of this document may be reproduced in any material form (including photocopying or storing it in any medium by electronic means) without the prior written permission of BBC Research & Development except in accordance with the provisions of the (UK) Copyright, Designs and Patents Act 1988.

The BBC grants permission to individuals and organisations to make copies of the entire document (including this copyright notice) for their own internal use. No copies of this document may be published, distributed or made available to third parties whether by paper, electronic or other means without the BBC's prior written permission. Where necessary, third parties should be directed to the relevant page on BBC's website at <http://www.bbc.co.uk/rd/pubs/> for a copy of this document.

# REVISED BACKGROUND NOISE CRITERIA FOR BROADCASTING STUDIOS

D.J. Meares, B.Sc.(Eng.), C.Eng., M.I.E.E., M.I.O.A.

K.F.L. Lansdowne

## 1. Introduction

In any sound programme chain there are a number of points at which noise is added to the signal, for instance, in the first stages of a microphone amplifier, in tape recorders and on the r.f. transmission path. A further source of noise which can be equally troublesome, but which is comparatively rarely referred to, is acoustic noise in the source studio. This occurs for many reasons, such as the proximity of ventilation plant or air turbulence in the ventilation trunking, the presence of technical equipment in the studio, structure-borne noises, etc., and just as tape-recorder noise has to be controlled if the programme is not to be degraded, so it is necessary to control acoustic noise. For this reason it has long been the practice in the BBC to specify a maximum permitted acoustic noise level for studio areas in the form of a steadily decreasing curve of sound pressure level against frequency (see Fig. 1). Similar arguments apply to control rooms and other monitoring areas where there is a need to assess the quality of the programme, and up to the present, the same criteria have been used for these areas. The shape of the curve was derived<sup>1</sup> from a long series of experiments starting in about 1961 and roughly reflects the ear's sensitivity to sound at low sound

pressure levels. The noise levels were, however, set as a compromise between the overall cost of the studio and the quality of programme output: they were defined as the 'maximum tolerable background noise due to all sources' for three classes of studios. It was acknowledged that they represented a situation that was less than perfect, even then.

Since these noise criteria were introduced, many factors have changed. First, many other parts of the programme chain, such as the distribution links and domestic receivers have gradually been improved and this has steadily exposed the acoustic noises. Secondly, significant improvements in the design of ventilation plant, particularly the advent of centralised systems, make it much easier now to produce a 'quiet' installation. It is also relevant to note that very many more people are now listening to v.h.f. transmissions, and are more critical of the quality of programmes.<sup>2</sup> Thus, it is appropriate to reconsider the problem of studio background noise criteria to establish what changes are justified and to consider what secondary effects such changes would have.

This Report approaches the problem using data on studio sound pressure levels for different types of programme, and estimates the signal-to-acoustic noise ratios that would be expected at the output of each type of studio. These are compared with the signal-to-noise ratios applicable to other parts of the broadcast chain and finally, recommendations are made to establish new criteria for background noise in studios.

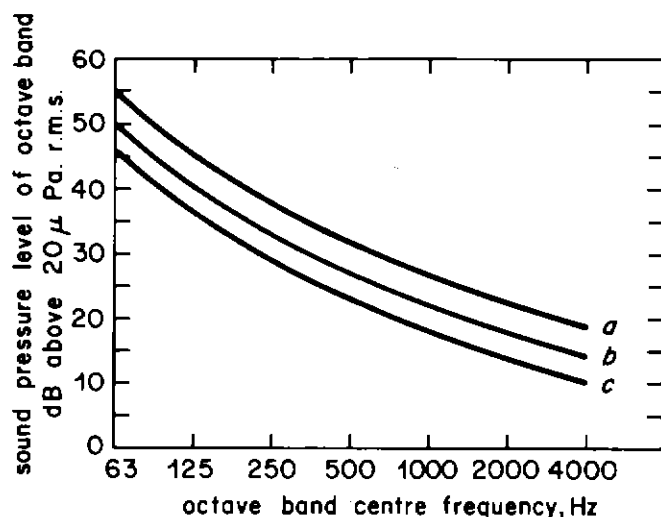


Fig. 1 - Original BBC criteria for permissible background noise in studios, from all sources (octave bands)

(a) Sound studios for light entertainment

(b) Sound studios (except drama). All television studios

(c) Sound drama studios

## 2. Studio sound pressure levels

A survey of studio sound pressure levels, reported elsewhere<sup>3</sup> has supplied a great deal of information on the temporal and spectral variations of the signals corresponding to various types of sound programme. Although the survey was carried out a number of years ago, only the sound pressure levels associated with amplified music are likely to have changed, and thus most of the survey results for studios are still relevant.

Studio recordings were made using a calibrated omni-directional microphone placed in the

TABLE 1

*Sound Levels in Studio Survey (dB, w.r.t. 20µPa, Linear Weighting to nearest dB)*

Programme Type	Maximum Level within Sample		Group Average	Number of Samples
	Quietest Sample	Loudest Sample		
Talks	76	89	81	13
Drama	71	86	77	10
Music-Recital	91	108	97	10
Music-Orchestral	93	110	102	20
Music-Dance Band	100	115	108	12

semi-reverberant sound fields and were later analysed using a 1/3rd octave spectrum analyser with the time constant of 100 ms.\* Further computer processing of these results produced a range of maximum sound levels for different types of programmes and different samples of the same type of programme: these are shown in Table 1. Pop music was also measured, but as most of it is of electronic origination and as it is on average very much louder than other types of programme, it is less relevant in the context of a study of background noise.

### 3. Signal-to-acoustic noise ratio calculations for radio studios

Given the above table of maximum sound levels, it is a routine matter to estimate the signal-to-acoustic noise ratio that would be measured at the studio output. Several factors, however, have to be considered, such as source of noise, type of microphone, etc. These are dealt with below.

#### 3.1. Source of noise

Assuming that the sum total of all acoustic noise in the studio just reaches the present background noise criterion in each frequency band, it is possible to calculate the sound pressure level at the microphone caused by the noise. Using the weighting network given in CCIR Recommendation 468<sup>4</sup> the resultant noise levels are as shown in Table 2.

\* This corresponds to the RMS FAST setting of a precision sound level meter.<sup>5</sup>

TABLE 2

*Equivalent Weighted SPL of Studio Noise*

BBC Criterion	a	b	c
Weighted Noise Level (dB, w.r.t. 20µPa)	37	32	28

#### 3.2. Current method of measuring signal-to-noise ratios

In the BBC the current method of quantifying signal-to-noise ratios is to peak the programme to PPM 6 and the noise to PPM 4.\* Thus, to a first approximation, the signal-to-noise ratio would be given by:

$$S/N = (\text{signal level} - \text{weighted noise level} - 8) \text{ dB}$$

However, a correction is needed for the fact that both the studio sound pressure levels and the background noise levels are, by convention, measured on an RMS meter,<sup>5</sup> whilst signal-to-noise measurements are measured on a quasi-peak reading meter.<sup>4</sup> Given that both types of meter are calibrated using sinewave signals it can be expected that different readings will be given by the two meters when measuring either noise or real programme signals. The difference between readings on an RMS meter and on a PPM has been shown for white noise to be 4.2 dB<sup>1</sup> & <sup>6</sup> and for ventilation noise to be 5 dB.<sup>1</sup> The latter figure will be used here for studio background noise. No

\* Note — the standard PPM is calibrated in 4 dB steps.

reference was, however, found to the differences that might be expected for programme signals and so a short experiment was carried out to quantify this. It showed for speech, pop music and classical music that the difference between peak and RMS programme levels was  $3 \text{ dB} \pm 1.5 \text{ dB}$ . As might be expected speech showed the greatest difference, whilst the more continuous sounds of an orchestra showed the least. The average figure of 3 dB's will however be assumed to be sufficiently representative, in comparison to the spread of levels shown in Table 1, to be used for all types of programme. Thus combining these two corrections the signal-to acoustic noise ratio becomes:

$$S/N = (\text{signal level} - \text{weighted noise level} - 10) \text{ dB4w.}^*$$

### 3.3. Microphone type

As already mentioned, the studio sound pressure level survey was carried out using an omni-directional microphone. In radio studios, it is normal to use directional microphones to reduce the sensitivity to diffuse sources of noise, such as ventilation: typical microphones would have cardioid or figure-of-eight polar responses. Theoretically, perfect cardioid or figure-of-eight microphones would both be 4.8 dB's less sensitive to diffuse noise than would an omni-directional microphone (see Appendix I). Imperfections in the microphones would, however, tend to reduce this slightly and so a figure of 4 dB's will be used here.

In addition, some types of microphone when used in, say, talks programmes exhibit a bass rise due to the proximity effect, and this is normally corrected by equalisation. Such equalisation would tend to reduce the low frequency content of any acoustic noise picked up by the micro-

phone, giving a slightly improved signal-to-acoustic noise ratio. However, since the equalisation is only of the order of 3 dB's at 100 Hz falling to 1 dB at 200 Hz, and since not all types of microphone exhibit this characteristic, the effect of such equalisation on the signal-to-noise ratio will not be included here.

### 3.4. Position of microphone

During the survey the measurement microphone was normally placed in the semi-reverberant sound field. In the case of recital and orchestral music, it is common practice to attempt to capture the natural reverberation of the recording venue and thus the survey microphone positions were probably correct in these studios. In contrast in talks studios, and for recording dance band music, the microphone would more probably be placed in the near field, i.e. about 0.5 m from the source. In drama studios the microphone is generally between these two extremes, a distance of 1.5 to 2 m from the source being typical. The survey figures for talks, drama and dance band music have, therefore, to be corrected for distance from the source, a correction which will vary with size of studio and degree of sound absorption in the studio. Typical corrections are given in Table 3.

### 3.5. Signal compression

The above estimates are calculated on the basis that the studio-desk gain is adjusted to make the loudest passage of each of the samples just peak to PPM 6 at the studio output, and that the studio-desk gain is unaltered during the recording. This is obviously not a true representation of a typical programme production where the studio manager will adjust the desk gain as the programme proceeds. The effect of this manual compression is to increase the signal *and* acoustic noise during the quieter passages of the programme, which will tend to

\* The nomenclature 'dB4w' has recently been adopted by the BBC for signal-to-noise ratios, where '4' signifies that the signal level peaked PPM6 whilst the noise peaked PPM4, and where 'w' signifies the use of CCIR Recommendation 468 weighting.

TABLE 3

*Correction for Microphone Positions*

Programme Type	Studio Volume (cu m)	Reverberation Time (secs)	Correction (dB)
Talks	90	0.3	+6
Drama	640	0.4	+3
Dance Band	1100	0.5	+11

TABLE 4

*Estimated Signal-to-Acoustic Noise Ratios for Radio Studios (dB4w, to nearest dB)*

Programme Type	Current Noise Criterion	Quietest Sample	Loudest Sample	Group Average
Talks	b	36	49	41
Drama	c	37	53	43
Music — Recital	b	45	63	51
Music — Orchestral	b	48	64	56
Music — Dance Band	b	66	80	74

reduce the signal-to-noise ratio for the programme as a whole. A short survey\* of typical network radio studio operations was carried out in connection with this study which showed that, for talks and music programmes, manual and/or electronic compression was typically between 7 and 12 dBs with an average of about 8 dBs. Thus, the estimated signal-to-noise ratios should be reduced by this amount. The compression applied to drama programmes was much more difficult to ascertain as level changes are required specifically for dramatic purposes. Furthermore, the drama producer has much more freedom to move the artists around until he gets the signal level he requires. However it is felt that about 3 dBs compression would be representative here.

### 3.6. Signal-to-noise ratios

Using the above corrections it is possible to estimate the signal-to-acoustic noise ratios that

\* This survey was carried out by D.G.M. Stripp of BBC Radio O & M Department.

would be found at the studio output. For radio studios the calculated figures are shown in Table 4.

### 4. Noise levels in television studios

Although the sound survey<sup>3</sup> was only conducted in radio studios, it is possible to adapt\* the results in order to assess television noise criteria. In general the adapted sound levels for television studios require the same corrections as for radio studios, the only change required is in the correction for microphone position. In drama programmes it is normally essential for the microphone not to be within camera shot and thus a relatively distant microphone position is often used. Discussion programmes and quiz games, in contrast, use close microphones, clearly within the view of the camera. Finally, as the majority of television studios do not have an acoustic of concert hall quality, many music programmes are also recorded using close microphones. The

\* The source power level is computed from the survey results and then the SPL for a similar source in a television studio is calculated.

TABLE 5

*Estimated Signal-to-Acoustic Noise Ratios for Television Studios (dB4w, to nearest dB)*

Programme Type	Current Noise Criterion	Quietest Sample	Loudest Sample	Group Average
Talks	b	36	49	41
Drama	b	30	46	36
Music — Recital	b	53	71	59
Music — Orchestral	b	45	61	53
Music — Dance Band	b	66	80	74

exception to this is for orchestral music where a distant microphone technique is used to exploit the natural balance of instruments. On this basis, the signal-to-acoustic noise ratios have been recalculated for television studios: these are given in Table 5.

## 5. Measurements on radio and television programmes

In order to check the above figures of signal-to-acoustic noise ratios, measurements were made on radio and television programme signals as they were being broadcast. These indicated typical signal-to-noise ratios (all forms of noise) on the broadcast programmes and an aural assessment was made to identify the main source of noise at any instant. Those times where acoustic noise was the limiting factor were noted and the signal-to-acoustic noise ratios were tabulated. Obviously for programmes where high signal-to-acoustic noise ratios are expected, such as dance band music, other factors limited the signal-to-noise ratio. Thus, this technique can only be used to check the results for programmes with comparatively low signal-to-acoustic noise ratios, such as talks and drama.

TABLE 6

*Measured Signal-to-Acoustic Noise Ratios  
(dB4w to nearest dB)*

Programme Type	Quietest Sample	Loudest Sample	Group Average
Radio — Talks	33	45	40
Radio — Drama	38	46	42
Radio — Orchestral	40	51	47
TV — Talks	36	51	45
TV — Drama	30	42	36

Table 6 shows the results of these measurements for those types of programme judged to be limited by acoustic noise. The figures for radio talks and drama compare well with the corresponding figures in Table 4. Radio orchestral programmes appear to have worse signal-to-noise ratios than the estimated figures of Table 4, but other factors, such as tape recorder noise and electrical noise on the monitoring circuit limited the measurements to a maximum somewhere between

52 and 55 dB4w and thus the orchestral programmes with high signal-to-acoustic noise ratios are not truly represented by Table 6. The television talks programmes show the same lower limit in Tables 5 and 6, but the good programmes were found to be better than had been estimated. On most occasions this was attributable to the speaker wearing an electret microphone clipped onto clothing (typically the lapel or tie) about 20 cms from the mouth, rather than the 50 cms used in the estimations of Table 5. This could easily account for the 3 dB 'improvement' for the better samples. Television drama shows a good match between the estimations Table 5 and the measurements Table 6. Thus, in general terms, Table 6 confirms the estimations given in Tables 4 and 5.

## 6. Comparative signal-to-noise figures

Geddes<sup>7</sup> reports a detailed study into both the quantitative and subjective assessment of various forms of noise, including simulation of studio ventilation noise. He devised a subjective criterion which he termed the 'signal-to-noise ratio at impairment threshold', i.e. the signal-to-noise ratio for different programmes and types of noise at which his subjects considered that their enjoyment of the programme was beginning to be impaired. Note this is an assessment in relationship to *impairment* due to noise, not just audibility of the noise. As a rough guide, an unpublished study found that for octave bands of noise superimposed on speech and music the noise was judged to be still audible at a level 5 to 10 dBs below the level which caused impairment.

For both music and speech with studio ventilation noise as the unwanted signal, Geddes found that the impairment threshold was at a signal-to-noise ratio of 49 dB4w,\*† whilst the quietest programme samples he encountered had a signal-to-acoustic noise ratio of about 36 dB4w for talks and 51 dB4w for music.

Comparing Geddes' impairment threshold against the figures in Tables 4 and 5, talks and drama programmes from both radio and television studios should be considered to be impaired by

\* These figures have been corrected from Geddes' due to the way in which signal-to-noise ratios are now measured, i.e. using the weighting network given in CCIR Recommendation 468 and peaking the noise to PPM 4.

† This result is for a monophonic programme. Geddes compared mono with stereo using white gaussian noise and found the listeners appeared to want about 1 dB lower noise level for stereo reproduction.

studio background noises. Most television music programmes compare favourably with the impairment threshold, but the quieter music recitals and orchestral broadcasts from radio studios and the quieter television orchestral programmes may be considered to be impaired. It is significant to note that Geddes himself concluded:

'For live speech programmes, acoustic noise picked up in the studio becomes excessive at the studio output whenever high gain is necessary; there is therefore a case for tightening the tolerances applied to ambient noise.'

Comparison of the subjective effect of ventilation noise with other forms of noise, such as tape recording noise, is made difficult by the different characteristics of the noises. However, the Geddes' impairment threshold can be used in this context to provide a useful method of comparison. Measurements on a modern 6 mm stereo tape recorder running at 38 cm/s for instance, gave a signal-to-noise ratio of approximately 48 dB4w per track. The additional use of noise reduction gave an improvement of 10 dB, to 58 dB4w. For comparison, Geddes found that the impairment threshold for tape noise was 46 dB4w.

Unlike tape noise, which will occur at the studio output at a more or less constant level, microphone noise varies linearly with the gain in the circuit. It will thus be most apparent on those programmes which require the highest gain, such as quiet talks programmes. The relative levels of speech, microphone noise, tape noise and studio acoustic noise are shown in Fig. 2, as they would occur at the output of a talks studio. The level of speech is that of the quietest 'talks' sample and the microphone gain has been calculated so that the loudest passage just peaks PPM 6 (+8 dB rel. 0.775 volts). (The effect on the noise levels of manual compression has been included.) It can be seen that acoustic noise very significantly outweighs both tape and microphone noise except at the higher frequencies (i.e. above 4 kHz).

With a digital sound system it is not possible to measure directly the noise generated by the finite accuracy of quantisation, simply because the quantisation noise is only present whilst the signal is there. It is normal, therefore, to assess quantisation noise by subjective comparison with true white gaussian noise, which can be measured directly. In this manner it has been shown<sup>6</sup> that the ratio of signal-to-quantisation noise is given by:

\* This equation is also modified in accordance with the present signal-to-noise ratio measuring technique.

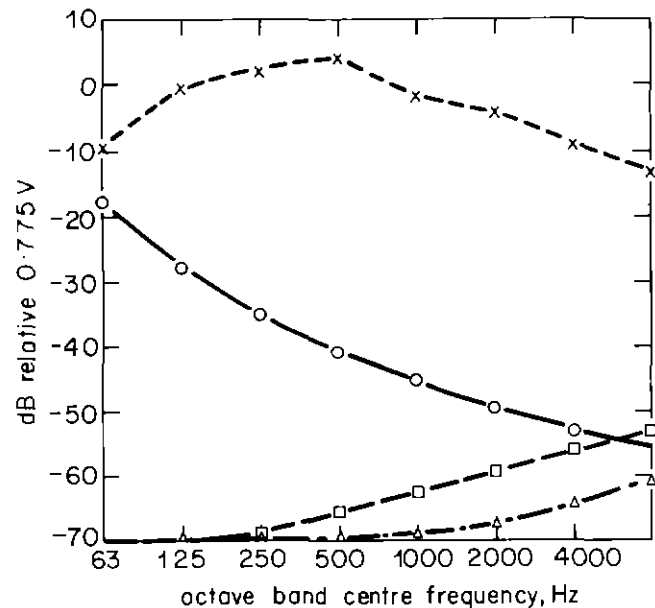


Fig. 2 - Signal and noise levels at the output of a talks studio

x — x Speech    O — O Studio acoustic noise  
□ — □ Microphone noise    Δ — Δ Tape noise

$$20 \log_{10} \frac{(\text{peak signal})}{(\text{peak weighted e.w.g. noise})}$$

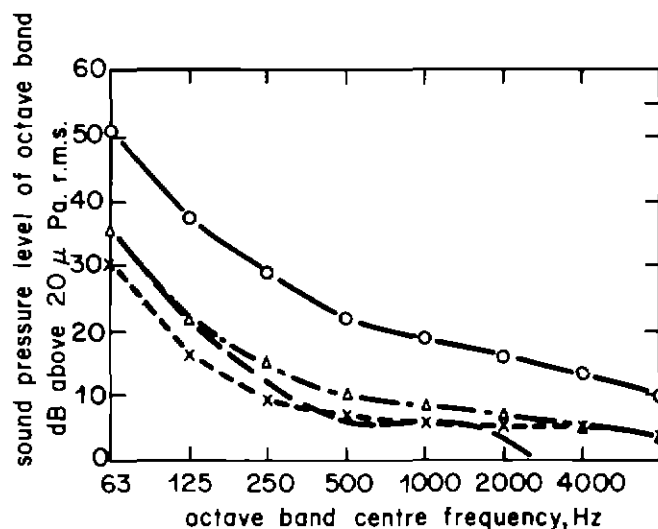
$$= (6n - 19) \text{ dB4w}$$

where  $n$  = number of bits per audio sample, and e.w.g. = equivalent white gaussian.

Thus, for a 13-bit PCM system, the level of quantisation noise is equivalent to white gaussian noise at a signal-to-noise ratio of 59 dB4w. In this case, the impairment threshold given by Geddes is 48 dB4w.

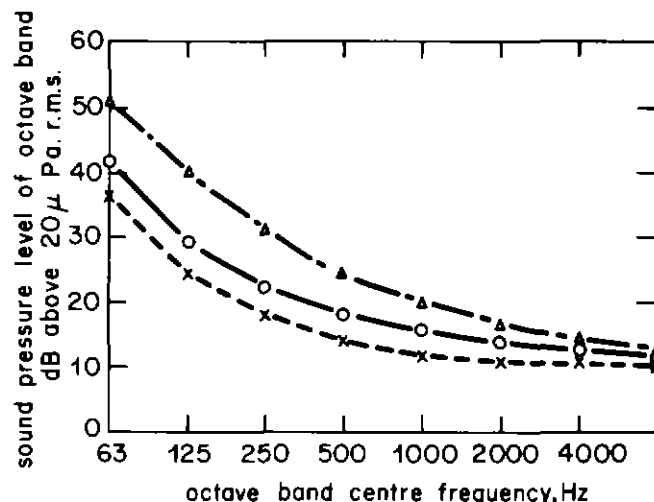
Even the domestic receiver is seldom the limiting factor in the chain. It is common with a v.h.f. tuner to find that the pauses between programmes or between announcements and the Greenwich Time Signal are accompanied by a significantly quieter background noise level. Indeed some of the measurements reported in Section 5 were made via a v.h.f. tuner receiving signals from the BBC Wrotham transmitter. During network fades the noise level was below the lowest level that could be measured reliably. It is, thus, valid to conclude that many receivers are capable of conveying programmes with source signal-to-noise ratios well in excess of 50 dB4w.

It is also relevant to consider the background noise criteria used by other broadcasting organisations. The German Broadcasters, represented by



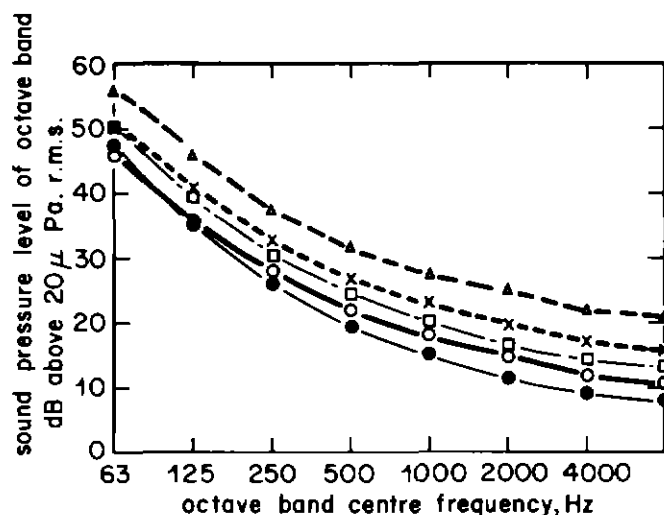
(a) As recommended by IRT

x---x Radio Studios    o——o TV Studios  
 Δ---Δ Control Rooms  
 --- Threshold of hearing for octave band noise<sup>10</sup>



(b) As used by ORF

x---x Radio Studios    Δ---Δ TV Studios  
 o——o Control Rooms



(c) As used by other organisations (see Table 1)

o——o NC15    x---x NC20    Δ---Δ NC25  
 ●——● NR15    □---□ NR20

Institut für Rundfunktechnik (IRT), set themselves a very high standard for their studios as shown in Fig. 3(a).<sup>8 & 9</sup> When designing a radio studio they specify a noise level which is better than or equal to the threshold of hearing at all but the highest frequencies. This is up to 20 dB below even BBC criterion c. The justification for going below the threshold of hearing at low frequencies is that when a recording is made of, say, quiet speech, more often than not when it is played back in the control room or in a listener's home it will be reproduced at a level up to 15 dB's higher. This is sufficient to increase the studio noise on the recording to well above the threshold level. At the higher frequencies other factors, such as

tape noise, becomes predominant and so the same argument does not apply. In the case of television studios, IRT accept that the presence of much technical equipment and many people (operators and artists) in the studio and the large volume of air which has to be changed by the ventilation system, make it impractical to specify as low a level as in the radio studios. The criterion they chose is, nevertheless, lower than the BBC's present television criterion, and even so they acknowledge that sometimes the ventilation system has to be switched off during the quieter dramatic sections of programme. Furthermore, the broadcasting organisations in Germany recently held a seminar<sup>11</sup> at which they discussed whether or not they could

TABLE 7

*Organisations using Noise Criterion (NC) or Noise Rating (NR) Curves*

Organisation	Radio	Television	Control
DR	NR 15	—	NR 20
SR	NC 15	NC 20	NC 20
NHK	NC 15	NC 25	—
NOS	NR 20	NR 20 to 25	NR 25
ABC (Australia)	NR 15 to 20	NR 20 to 25	—
RTE	NR 15 to 20	NR 22	NR 20 to 22

relax their noise criteria. They, concluded, however, with much supporting evidence, that the low noise levels were essential for them to maintain their existing programme standards.

The Austrian broadcasters, ORF, also have fairly stringent criteria for radio studios and control rooms, as shown in Fig. 3(b). These are not as stringent as those recommended by IRT, but they are still significantly lower than the BBC criteria of Fig. 1. The television criterion is within 2 dB's of the IRT specification.

Other organisations use one of two groups of noise curves, either the ISO Noise Rating Curves<sup>12</sup> or Beranek's Noise Criterion Curves.<sup>13</sup> Appropriate curves are shown in Fig. 3(c), whilst Table 7 shows which criteria each organisation uses.

For comparison, BBC criterion b is approximately equivalent to NC 20 and NR 20 at mid frequencies. Thus, whilst the criteria used for television studios by those organisations listed in Table 7 are equivalent to the BBC criterion, the criteria used for radio studios by DR, SR and NHK are more stringent than the BBC criterion b.

It may therefore be concluded that not only are the BBC's criteria for background noise in studios inadequate in comparison to many other parts of the broadcast chain, but in several cases, they are now below the standard set by other broadcasting organisations.

## 7. Revised criteria

In view of the points raised above, it is recommended that the BBC criteria for background noise in studios should be revised to reduce the level of

acoustic noise on the output from certain classes of studios. The types of studio which require the lower level of noise are radio talks,\* drama and music recital and television talks\* and drama. The television studios used for some of the quieter orchestral recordings would also benefit from lower background noise levels, but the gain would be less significant.

The position with regard to television studios is, however, complicated by the fact that most of them are general purpose, i.e. they must cope with anything from drama to pop groups. This is a direct consequence of the enormous capital investment in a studio and its equipment, and the BBC's desire to have the studio in operation for the greatest percentage of the time. The scheduling required to achieve this rules out the concept of television studios being specialised to the production of one type of programme. Thus, for television studios, it is necessary to select a single criterion which, whilst not being exorbitantly expensive to achieve, nevertheless, gives a reasonable quality for drama without the need for continually switching off the ventilation system. This compromise is made below in the selection of a television criterion.

During this study, serious consideration was given to the question of whether the BBC was right to continue to use its own locally derived curves for background noise or whether it could adopt curves from, say, the internationally recognised NR series. Several factors were found, however, which strongly support the BBC's shape of curve. Most importantly the use of an NR curve would allow up to 9 dB's more low frequency

\* In this context 'talks' includes continuity studios.

noise, relative to the average level between 250 Hz and 1 kHz, than would a BBC curve. Since it is invariably the low frequency studio noise that is audible on the programme output, a 9 dB increase in this range would not be acceptable. Secondly the curvature of the BBC criteria closely matches the shape of noise spectra that typical ventilation systems produce. The average ventilation noise spectrum for more than fifty radio talks studios that have been tested since 1970 matches the curvature of the BBC criteria within  $\pm 1$  dB from 50 Hz to 3 kHz; the BBC criteria are obviously, therefore, realisable in practice. Finally, the average slope of the BBC curves matches well the slope of the 'A' weighting curve<sup>5</sup> below 1 kHz and the slope of the CCIR weighting<sup>4</sup> below 4 kHz. Thus, although it could be useful contractually to adopt the NR curves, a great deal of evidence supports the continued use of curves of the shape of the BBC criteria a, b and c. It is recommended, therefore, that this type of curve continue to be used.

It is further recommended that the criteria should be more specific. The previous criteria were described as 'permissible background noise criteria, from all sources'. This was intended to imply that each source of noise should be less than the criterion so that noise from all sources summed together would still meet it. In fact this has seldom been the case, and in many instances, through a misunderstanding, the ventilation noise on its own only just meets the criterion. Thus the new criteria should be for ventilation noises only and an adjustment of 3 dBs made to allow for other sources of noise. It is relevant to add that when a studio is in use, a programme microphone will pick up only that level of noise which exists at its position in the recording studio, i.e. it does not pick up a noise level equal to the average noise throughout the studio. Thus ventilation noises should meet the criterion at any normal microphone position – it is not enough for the average noise level to just meet the criterion.

Finally, it is current practice to specify the spectrum of noise in terms of the levels in one-third octave bands and thus the new criteria for ventilation noise refer to one-third octave band analysis, rather than octave band analysis. The revised criteria, taking into account all the above factors, are shown in Fig. 4. These are grouped according to studio classification. The only occasion where confusion might arise is where a studio is used for more than one purpose, e.g. an orchestral studio used also for recital programmes. Under these conditions, the studio should be designed to the lower (quieter) noise criterion.

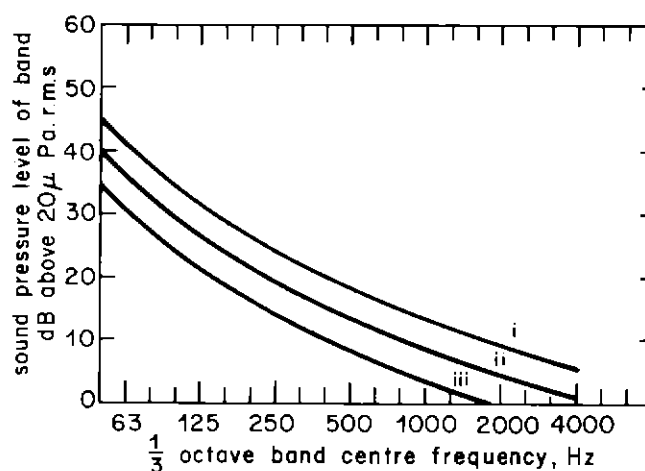


Fig. 4 - Revised BBC noise criteria  
Maximum tolerable background noise in studios  
from ventilation

- (i) Radio – other than classes (ii) and (iii)
- (ii) Radio – talks, continuity, recital. Television all categories
- (iii) Radio – drama

The criteria shown in Fig. 4 cover the frequency range 50 Hz to 4 kHz (or 2 kHz for curve (iii)). Outside that range, a degree of control of noise levels is still necessary even though it is less critical from the acoustic pick-up point of view. Other factors outside the scope of this report, such as comfort of personnel, may impose their own limits: these, however, are not discussed here. To minimise acoustic noise pick-up at low frequencies, the ventilation noise levels should be constrained so that they rise by no more than 12 dBs per octave below 50 Hz. At higher frequencies, i.e. above 4 kHz (or 2 kHz for curve (iii)), where microphone and tape noise will normally become the limiting factors, the ventilation noise levels should wherever possible, continue at the level allowable in the 4 kHz band (or 2 kHz for curve (iii)). Under no circumstances, however, should the levels rise by more than 3 dBs per octave.

In addition, it is known that a noise with a pronounced tonal quality or cyclic variation is subjectively more disturbing than a noise of similar sound pressure level, but no distinct quality. If a ventilation system, for instance, had a pronounced peak in its noise spectrum even if the noise level at that peak were just below the criterion, the installation would almost certainly be unacceptable. The sensitivity to such discontinuities in spectrum and to cyclic changes in a noise varies considerably with frequency and sound pressure level, but experience indicates that where a noise exhibits tonality or variability, its level should be limited to 5 dB below the normally accepted criterion.

TABLE 8

*Noise Criteria for Studios and Cubicles*

Studio Usage	Studios	Control Cubicles
<b>RADIO</b>		
Drama	(iii)	(ii)
Talks	(ii)	(ii)
Continuity	(ii)	(ii)
Music – Recital	(ii)	(ii)
Other categories	(i)	(i)
<b>TELEVISION</b>		
All categories	(ii)	(ii)

The case of control cubicles must also be considered here. Whilst not normally containing live microphones,\* these are the areas in which all aspects of programme quality are assessed, and this includes an assessment of the amount of noise on the programme. Thus, although there may not be a need in a drama cubicle for the extremely low noise levels required in the studio, the cubicle has to be sufficiently quiet for the required technical assessments to be made. There is also the fact that many radio cubicles have tape recorders and disc players running during the programme which would undoubtedly become the limiting factor in the background noise levels. It is therefore recommended that where a studio is designed to meet criterion (iii) the cubicle should be designed to a criterion 5 dBs less stringent. Other cubicles should be designed to be same criterion as the studio. This is shown in Table 8.

In the case of TV control rooms, personnel in both the sound control rooms and the production control rooms have an executive responsibility for the quality of the programme sound. These rooms should both therefore be designed to meet criterion (ii). However, there is no similar onus of responsibility for the programme sound quality on the personnel in the vision control rooms. Furthermore, these areas contain a great deal of technical equipment, much of it fan cooled, and thus a very quiet environment is unlikely to be achieved. It is recommended therefore that vision control rooms should be designed to meet a curve 5 dBs above criterion (i) in Fig. 4.

The only control areas not yet covered here are monitoring areas in CMCR's etc. These have

\* BBC Local Radio operations are somewhat different from network radio, and live microphones are often present in these cubicles.

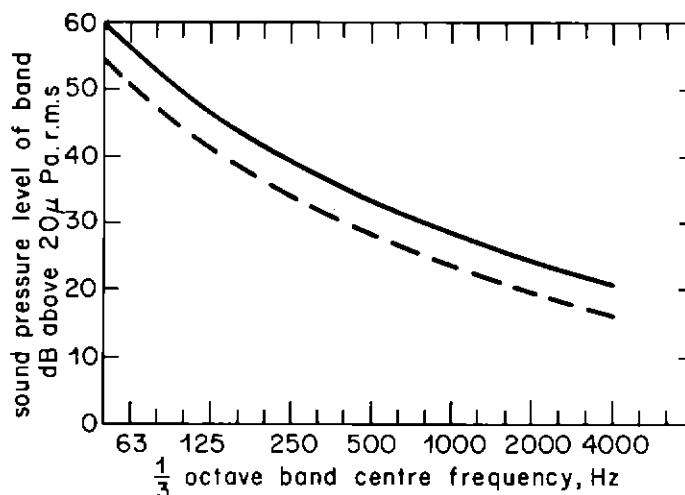


Fig. 5 - Maximum tolerable background noise in mobile control rooms from ventilation

———— CMCR's and other TV vehicles  
 - - - - - sound only vehicles

always been considered as special cases because of the difficulty of isolating the areas from outside noises and because of the proximity and quantity of ventilation and other equipment. In the past a holding specification<sup>1</sup> has been used. Experience since that time indicates that this holding specification is approximately correct for TV vehicles, in as much as it is realisable in practice. It is slightly modified here, see Fig. 5, so that it matches the slope of the other criteria and is presented in a one-third octave analysis form, for ventilation only. For 'sound only' control vehicles a slightly more stringent criterion is both desirable and, in the absence of fan cooled video equipment, achievable. This is also shown in Fig. 5. It is recommended that the total noise from all the other equipment in mobile control rooms should meet the same criteria.

In the case of equipment in other sensitive areas, i.e. studios and cubicles, it is recommended that each item be designed to meet a level 3 dBs below the relevant ventilation noise criterion when measured at a distance of 1 metre. This in itself is a compromise as one could postulate a situation where, say, many TV cameras and the ventilation system were each generating a noise level equal to its respective noise criterion; under such conditions the sum total could easily be in excess of the required maximum background noise level. However, it would not be economically sensible to cover all such possibilities, and whereas it is not uncommon to have two pieces of 'noisy' equipment, plus the ventilation system, within range of a live microphone, other more noisy arrangements are relatively rare.

## 8. Practical implementation

It is relevant to ask how practical the new noise criteria are. There is little point in specifying low levels for background noise in studios if the requirement is either physically impossible to meet or alternatively, is far too expensive to be used widely. Fig. 6 shows some example of occasions where the ventilation noise levels have been lower than normal.

Two special cases exist at Manchester and Maida Vale. At Manchester, the building design

incorporated a single centralised ventilation and heating plant area located away from most of the studios.

The unusually long duct runs enabled attenuation of duct borne plant noise to be achieved easily and thus low ventilation noise levels resulted. In the case of the pop studios at Maida Vale the acoustic design was required to contain the very high levels of pop music, to prevent interference with other areas. By reciprocity the measures that are taken to stop noise from getting out, will also prevent external noise from getting into the studios. Thus, although low noise levels are not really required in a pop studio,

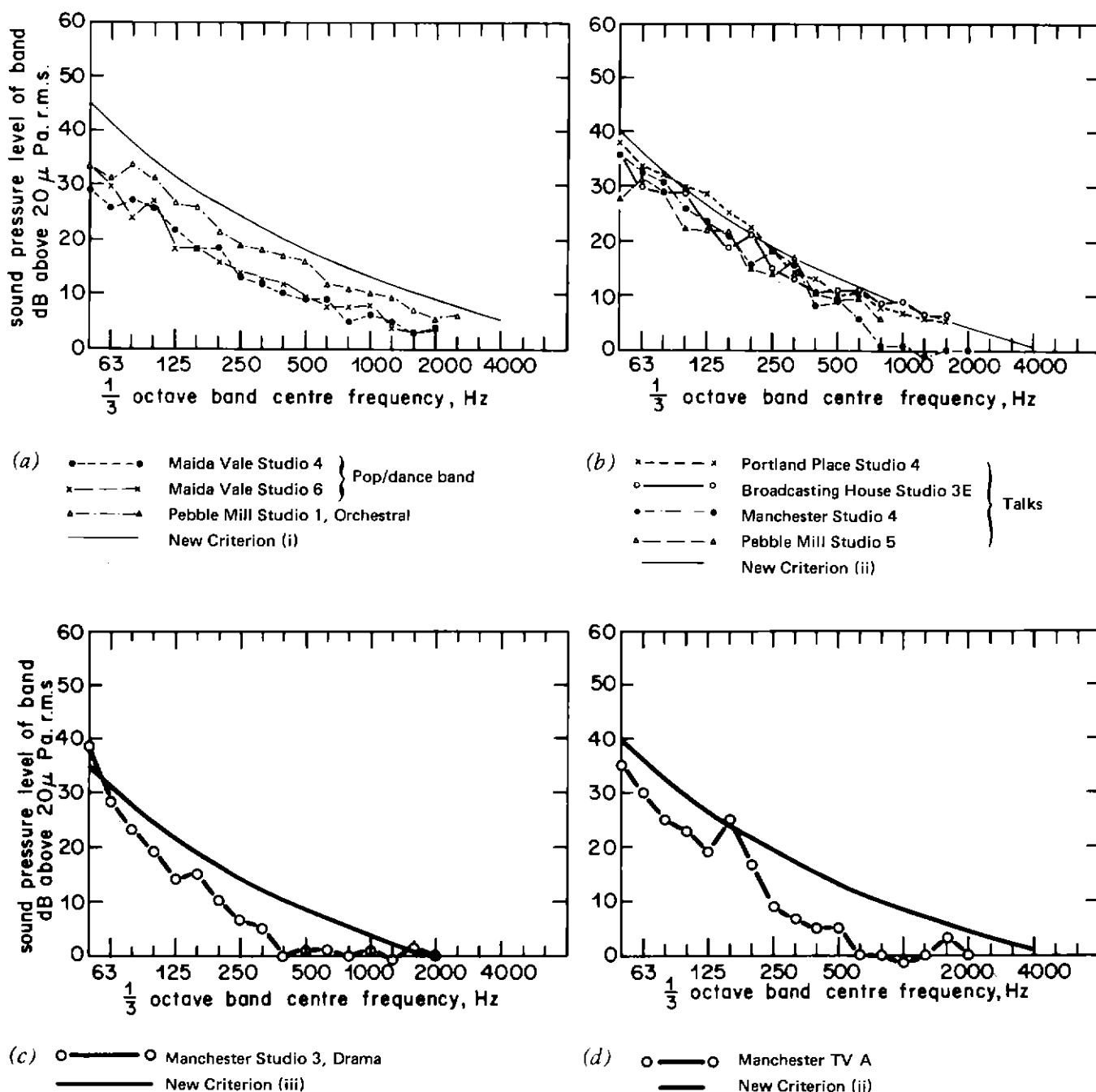


Fig. 6 - Comparison between new criteria and some of the better existing installations

they were achieved. It is interesting to note that the noise levels in Maida Vale Studios 4 and 6 (and Studio 5, not shown) very nearly meet the new drama noise criterion and when recently Maida Vale Studio 6 was used for a drama programme, the operators commented how much easier drama production was in a quiet studio.

The other cases shown in Fig. 6 received no special attention as was the case for the Manchester and Maida Vale studios. They demonstrate that by sensible design and adjustment of air flows, low levels of studio ventilation noise can be achieved. It may, therefore be concluded that the new ventilation noise criteria are achievable at what may prove to be a comparatively small cost, e.g. the cost of two extra duct attenuators. The main cost, however, could well be encountered in providing sufficient structural isolation<sup>14,15</sup> to reduce external structure-borne noises to the levels prescribed by the new criterion. This, however, is the subject of a separate study which will be reported in the near future.<sup>15</sup>

## 9. Conclusions

Even in 1968, it was found that studio acoustic noise could well be the limiting factor in the programme chain for many talks programmes. Since that time other parts of the chain have been improved, but the BBC is still using the pre-1968 criteria for studio background noise, and in many cases the studios barely meet these criteria.

Obviously, it would be uneconomic to design studios to be sufficiently noise-free to enable any programme, no matter how quiet, to be recorded entirely free of acoustic noise. In any case, beyond a certain point, other sources such as microphone noise would become the limiting factor. A difficult compromise has to be made between the cost of the studio (including ventilation plant) and the cost of programmes (many retakes are often required in drama productions solely because of noises in the studio).

New criteria, shown in Fig. 4, have been derived on the basis of data on studio sound pressure levels and impairment thresholds for ventilation noise and on experience with the 1968 noise criteria. In the case of radio studios, the most significant changes are for the talks, drama and recital criteria which are each 5 dBs lower than the earlier criteria. In the case of television studios current usage demands that virtually every studio should be general purpose and thus a general

television criterion is required. This has been selected as a compromise between the critical requirements of drama programmes, and the potential cost of further improvements. It should, however, ease some of the problems of television drama productions.

Recommendations have also been made in respect of ventilation noises which exhibit tonal or variable qualities, ventilation noise in control cubicles and noises from equipment in the studio or cubicle such as television cameras, tape recorders, etc.

Finally, it is worth pointing out that although the adoption of these criteria would significantly decrease the number of programmes that would otherwise be considered to be impaired by studio noise, the latter would still be the main source of noise on many programmes. Any further reduction of acoustic noise criteria would, however, place an intolerable burden on the requirement of sound isolation between areas. Even so, the consequences of the above recommendations should be studied and revised isolation criteria should be contemplated.

In considering the revised noise criteria, the direct cost in building terms must be balanced against the hidden cost and difficulties of trying to make high quality programmes in low quality, noisy environments: frequent retakes are both time consuming and frustrating to operators and artists alike. In general, studio structures are the longest term investment in broadcasting operations, and whereas technical equipment is often replaced or reallocated after ten years, the studios being built now, are likely to be in use for thirty years or more. During that time other parts of the broadcasting chain are liable to be improved; for instance, the widespread application of digital techniques in broadcasting has only become feasible in the last decade<sup>16</sup> and implementation of these techniques is, in many ways, still in its infancy. Such developments will make ever increasing demands on the quality of programme-signals leaving the studios. Thus money invested now in good studio design will more than repay itself during the life of the studio.

## 10. Acknowledgements

The author would particularly like to thank the various members of the BBC's Acoustics Committee for their helpful suggestions during the preparation of this report.

## 11. References

1. GILFORD, C.L.S. and JONES, D.K. Psycho-acoustic criteria for background noise and sound insulation in broadcasting studios. BBC Research Department Report No. PH-5, Serial No. 1967/11 (out of print).
2. McKENZIE, A. FM radio. *Hi-Fi News and Record Review*, March 1979, p. 89.
3. MEARES, D.J. Statistics of programme sound pressure levels in sound studios and their control rooms. BBC Research Department Report No. 1973/37.
4. Measurements of audio-frequency noise in broadcasting, in sound recording systems and on sound programme circuits. CCIR Recommendation 468-1.
5. Precision Sound Level Meters. International Electrotechnical Commission Publication 179, 1973.
6. HOWORTH, D. and SHORTER, D.E.L. Pulse code modulation for high-quality sound signal distribution. BBC Research Department Report No. EL-10, Serial No. 1967/50 (out of print).
7. GEDDES, W.K.E. The assessment of noise in audio frequency circuits. BBC Research Department Report No. EL-17, Serial No. 1968/8 (out of print).
8. Zulässige Schalldruckpegel von Dauergerauschen in Rundfunk und Fernsehstudios. (Allowable sound pressure levels for steady noises in sound broadcasting and television studios.) IRT Akustische Information 1.11-1, 1968.
9. Geräuschpegel in technischen Räumen und Zulässiger Pegel der Klimaanlage. (Noise levels in technical areas and allowable levels for air conditioning systems.) IRT Akustische Information 1.12-1, 1970.
10. ROBINSON, D.W. and WHITTLE, L.S. The loudness of octave bands of noise. *Acoustica*, 1964, **14**, 1, pp. 24 – 35.
11. PLENGE, G, KUHL, W. et al. Raum – und Bauakustische Anforderungen an Studio – und Regieräume des Hörfunks aus heutiger Sicht. (Room and architectural – acoustic requirements for sound broadcasting studios and control rooms from a present day viewpoint.) *Rundfunktechnische Mitteilungen*, October 1978, pp. 255 – 273.
12. Acoustics: Assessment of noise with respect to community response. ISO Recommendation 1996.
13. BERANEK, L.L. Noise reduction. McGraw-Hill, 1960, p. 519.
14. SMITH, T.J.B. and GILFORD, C.L.S. Airborne sound insulation requirements in studio centres. BBC Research Department Report No. PH-21, Serial No. 1968/35 (out of print).
15. WALKER, R. Revision of airborne sound insulation requirements in broadcasting studio centres. BBC Research Department Report in course of preparation.
16. REDMOND, J. Broadcasting: the developing technology. President's Inaugural Address, *Proc. IEE*, Vol. 26, No.1, Jan. 1979.

## Appendix I

### Microphone Directivity

For an omni-directional microphone the mean spherical response is given by:

$$\int_0^{\pi} 2\pi \sin \theta \, d\theta = 4\pi$$

For a hypercardioid given by the pressure response

$$p = \frac{1}{1+a} (a + \cos \theta)$$

the mean spherical response is given by

$$\int_0^{\pi} 2\pi \sin \theta \left( \frac{1}{1+a} (a + \cos \theta) \right)^2 d\theta = \frac{4\pi}{3} \frac{3a^2 + 1}{(1+a)}$$

Therefore, the relative sensitivity of a hypercardioid microphone compared to an omni-directional microphone:

$$= 10 \log_{10} \frac{3a^2 + 1}{3(1+a)^2} \text{ dB}$$

Thus the relative sensitivities of different microphones compared to an omni-directional microphone are shown in the following table.

Microphone Type	a	Relative Sensitivity
Figure-of-eight	0	−4.77 dB
Cardioid	1	−4.77 dB
Cottage Loaf	$\frac{1}{\sqrt{2}}$	−5.44 dB

## Appendix II

### Revised Criteria – Tabulated Values

The following table gives, for each criterion, the maximum tolerable sound pressure level in one-third octave bands in dB above 20  $\mu$ Pa r.m.s.

Band centre frequency	Noise Criterion				
	(i)	(ii)	(iii)	TV vehicles	Sound only vehicles
Hz					
50	45.0	40.0	35.0	60.0	55.0
63	41.0	36.0	31.0	56.0	51.0
80	37.5	32.5	27.5	52.5	47.5
100	34.0	29.0	24.0	49.0	44.0
125	31.5	26.5	21.5	46.5	41.5
160	28.5	23.5	18.5	43.5	38.5
200	26.0	21.0	16.0	41.0	36.0
250	24.0	19.0	14.0	39.0	34.0
315	22.0	17.0	12.0	37.0	32.0
400	20.0	15.0	10.0	35.0	30.0
500	18.0	13.0	8.0	33.0	28.0
630	16.5	11.5	6.5	31.5	26.5
800	14.5	9.5	4.5	29.5	24.5
1 k	13.0	8.0	3.0	28.0	23.0
1.25	12.0	7.0	2.0	27.0	22.0
1.60	10.5	5.5	0.5	25.5	20.5
2.00	9.0	4.0	-1.0	24.0	19.0
2.50	8.0	3.0	—	23.0	18.0
3.15	6.5	1.5	—	21.5	16.5
4.00	5.5	0.5	—	20.5	15.5

